of *Jupiter's* equator. The position of this plane is assumed in accordance with Damoiseau's determination.

The planes of the orbits of the Satellites, so far as they can be deduced from the unsatisfactory data available, have at present the following inclinations to *Jupiter's* equator:—

1876.	Sat. I.	Sat. II.	Sat. III.	Sat. IV.
Jan. 6	0°·0092	0°·4452	0°·2062	0°·3354
Mar. 6	93	·4461	·2051	·3350
May 5	94	·4470	·2041	·3344
July 4	95	·4478	·2030	·3336
Sept. 2	0·0096	0·4486	0·2020	0·3326

and their corresponding ascending nodes, reckoned from the descending node of *Jupiter's* equator on his orbit, are the following:—

1876.	Sat. I.	Sat. II.	Sat. III.	Sat. IV.
Jan. 6	57°·2	63°·76	278°·03	330°·16
Mar. 6	49·6	61·70	277·59	330·26
May 5	48·0	59·65	277·11	330·34
July 4	46·4	57·62	276·60	330·41
Sept. 2	45·1	55·60	276·07	330·46

On the Proper Motion of Bradley's Stars.

By John J. Plummer, Esq.

As the necessity for the publication of an authoritative Catalogue of Stars to take the place of the now rather antiquated compilation of the British Association is daily becoming more apparent, some results which I have arrived at with the view of determining which of the brighter stars have had their places least accurately determined may be of interest. Since the publication of the British Association Catalogue in 1847, all the brighter stars have been so frequently and carefully observed that no doubt can be entertained regarding the accuracy of the places of them to be derived from modern authorities; but, owing to the fact that their proper motions must depend almost entirely upon the old observations of Bradley and Piazzi, inaccuracies in one or other of these catalogues would injuriously affect their places after even a few years' interval. It is perfectly well known that many of the proper motions of stars in the British Association Catalogue founded on a comparison of Bradley or Piazzi with Taylor and other modern observations are quite untrustworthy; and though many of these have been corrected by the later and more accurate investigations of Messieurs Main and Stone, there yet remain not a few instances in which no better results have been published. It is a question, therefore, whether the greater

accuracy of modern observation does not to a considerable extent compensate for the less interval of the time elapsed, and whether at least as satisfactory proper motions may not now be obtained without having recourse to the older observations. Again, I do not know that we have any right to assume that proper motion is in all cases constant both in direction and amount during the long interval of 120 years which has elapsed since Bradley's observations, and indeed I believe that I have already discovered some evidence to the contrary ; and lastly, the invariable use of Bradley's Catalogue, owing to the great value which time has given to it may have an undue tendency to introduce systematic error into the results obtained by its use, which it is only possible to eliminate either by a thorough discussion of all the observations that are available, or by reducing the proper motions from modern observations without their aid and comparing them with the more generally received values.

If we add, that as our knowledge of the proper motions of stars in the direction of the line of sight increases, investigations into their proper motions, at right angles thereto will have an increasing interest, it will be seen that there was more than sufficient inducement to attempt the determination of proper motions from modern observations alone ; at least a comparison of results would show where the accepted proper motions are erroneous or doubtful, and a re-observation of these cases would be exceedingly serviceable (whenever a new compilation may be made) in helping to trace back the origin of the error to the older authorities, I have commenced this investigation by a comparison of the "Armagh Places of Stars" with the last published Greenwich 7-year Catalogue, there being more than 2,000 stars common to both, and very frequently an interval of 25 to 35 years between their mean dates. Moreover, the accuracy of the Armagh Catalogue left nothing to be desired, and as an authority for star places is unquestionably superior to any other of the like date. Still it was necessary to fix upon some limit of probable error below which any difference between the catalogues was to be regarded rather as error of observation than as evidence of change of place ; and, after some consideration, it was determined that owing to the great care displayed in the construction of the Armagh Catalogue as well as in that of Greenwich, and having regard to the number of times that stars have been observed in each, it would be unjust to the reputation of these works to fix a higher limit than $\pm 0^{s}.25$ in Right Ascension and $\pm 2''.50$ in Declination. Whenever a star brought up by the use of the received proper motion from the earlier catalogue differed by more than this amount from the place given by the later one it was considered that there was a fair case for inquiry as to whether the proper motion employed was correct. It being but comparatively seldom that the place in either catalogue depended on less than three observations, this assumption is equivalent to the supposition that a single observation in Right Ascension in either catalogue is

liable to a probable error of about $\pm 0^s \cdot 216$, and in Declination of $\pm 2'' \cdot 16$, which may perhaps be held a fair estimate, though intentionally erring (if anything) upon the side of excess. In the case of stars near the pole a still greater limit of error in Right Ascension has been allowed, for though disinclined to believe that the probable error for a northern star would increase so rapidly as the secant of the Declination, it is certain that it increases in some ratio. It has been my practice to assume that if P.E.= the probable error in Right Ascension for an equatoreal star, the probable error (p.e.) for any star whose declination is δ may be expressed by the formula p.e.=P.E. sec.$\frac{1}{2}\delta$: a rule that experience has shown to be sufficiently accurate for practical purposes.

The following table will show the limits of probable error that have in effect been allowed for a single observation in R.A. in either Catalogue for each 10° of Declination:—

Declination of Star.	Assumed P.E. of single observation.	Declination of Star.	Assumed P.E. of single observation.
°	sec.	°	sec.
0	0·216	65	0·333
10	·218	70	·370
20	·223	75	·425
30	·233	80	·520
40	·248	82·30′	·599
50	·270	85·0′	0·734
60	0·307	87·30′	1·037

Notwithstanding this rather considerable latitude, not a few stars (as will be seen below) have been found which exceed the prescribed limits, and must be held as deserving of re-observation: a work that I have already commenced at the Durham Observatory, and hope to bring to a conclusion during the ensuing year.

The method that has been adopted to detect cases of discordance has been as follows. The total amount of geometrical precession in either element has been accurately computed by Bessel's constants, and the differences between the places in the chosen catalogues compared with this result. The excess of the latter over the former, having been divided by the interval between the mean dates of observation, gives the annual proper motion of the star as afforded by the two catalogues. Thus the proper motion of each of the 2,000 stars will be found and may at some time be published: at present it is only those which show large discordances that have engaged my attention. It having been the practice at the Greenwich Observatory to publish the mean places for the date of the catalogue, freed from proper motion, it has been first necessary to reduce the position back again to that of the day of observation, before comparison with the places given in the Armagh Catalogue: these latter, though reduced to 1840, are affected by the proper motions from the date of observation of each star, which in some cases is long anterior, and in others long subsequent to the above-mentioned

date. It was on account of the considerable interval of time over which the Armagh observations were extended, and of the use therein of Bessel's constants only, that I have preferred to employ these rather than the constants of Peters; but it is noteworthy, that since the values of log n given by Peters and Bessel are identical to the fifth decimal place, the resulting proper motions in Right Ascension are converted into those that would have been given by the use of Peters' constants by the addition of the constant quantity $-0^{s}.00116$, *i.e.* by the application of the difference of the value of the constant m as given by these authorities. The proper motions in Declination of course require no alteration.

Unfortunately it was very soon discovered that for the present all consideration of the proper motions in Declination must be abandoned. Whether it arise from the use of different refraction tables, or from a different method of applying zenith points, the two catalogues are not comparable, the declinations given by the Armagh observers being systematically greater by a small quantity than those given by the Greenwich observers. This portion of the discussion is necessarily postponed.

The following is the comparison of the proper motions in Right Ascension of those stars which present discordances exceeding the prescribed limits, with the proper motions published and used in the Greenwich 7-year Catalogue for 1864, and included in the first six hours of Right Ascension:—

Name of Star.	No. of Observations in		Proper Motion in R.A.		Difference.	Interval of time on which the result depends.	Approximate Declination.
	Green. Cat.	Armagh Cat.	From Green. Cat.	By computation.			
			sec.	sec.	sec.	years	°
Piazzi 0.73	9	8	−0·005	+0·0070	+0·0120	27·0	+ 1
45 Piscium	5	5	−0·001	+0·0075	+0·0085	31·9	+ 7
13 Cassiopeiæ	3	6	+0·037	+0·0042	−0·0328	12·8	+66
52 Piscium	6	7	+0·012	+0·0009	−0·0111	22·6	+20
13 Ceti	7	6	+0·017	+0·0291	+0·0121	31·5	− 4
32 Andromedæ	3	4	+0·012	+0·0065	−0·0185	18·1	+39
Piazzi 0.148	5	2	+0·033	+0·0046	−0·0284	14·7	+24
Piazzi 0.189	7	8	+0·039	+0·0509	+0·0119	29·2	+ 5
Bradley 95	2	9	−0·171	+0·0685	+0·2395	36·8	+86
Bradley 122	3	2	+0·007	−0·0131	−0·0201	12·6	+21
27 Ceti	4	1	0·000	−0·0133	−0·0133	3·64	−11
32 Cassiopeiæ	3	1	−0·050	−0·0047	+0·0453	22·7	+64
45 Andromedæ	3	2	−0·039	−0·0076	+0·0314	15·5	+37
36 Ceti	3	5	+0·005	−0·0075	−0·0125	25·1	− 8
Bradley 166 *	3	1	+0·015	−0.0492	−0·0642	13·7	+78
35 Cassiopeiæ	3	5	+0·038	+0·0136	−0·0244	23·4	+64

* There is probably an error of 1 second in the R.A. given by the Armagh Catalogue; three other stars have been excluded from the list upon a like supposition.

Name of Star.	No. of Observations in Green. Cat.	Armagh Cat.	Proper Motion in R.A. From Green. Cat. sec.	By computation. sec.	Difference. sec.	Interval of time on which the result depends. years	Approximate Declination. °
102 Piscium π	3	5	−0·007	−0·0277	−0·0207	20·7	+11
4 Arietis	4	6	+0·006	−0·0152	−0·0212	18·5	+16
1 Arietis	4	5	+0·009	−0·0030	−0·0120	34·4	+22
53 Ceti χ	6	5	−0·017	−0·0076	+0·0094	27·8	−11
7 Arietis	3	6	0·000	+0·0085	+0·0085	29·2	+23
112 Piscium	1	3	+0·017	+0·0380	+0·0210	15·1	+ 2
14 Arietis	3	2	+0·006	+0·0209	+0·0149	22·6	+25
66 Ceti	3	4	+0·036	+0·0180	−0·0180	19·6	− 3
29 Arietis	1	5	−0.007	+0·0022	+0.0092	28·1	+14
31 Arietis	3	3	+0·017	+0·0250	+0·0080	33·6	+12
Bradley 358	3	1	+0·051	−0·0141	−0·0651	13·1	+67
83 Ceti	2	4	+0·005	+0·0243	+0·0193	17·3	−12
Bradley 366	2	4	−0·001	−0·0844	−0·0834	9·3	+67
12 Persei	2	5	−0·002	+0·0091	+0·0111	27·5	+40
37 Arietis o	4	5	+0·003	−0·0251	−0·0281	20·1	+15
43 Arietis σ	39	5	−0·002	+0·0070	+0·0090	32·5	+14
6 Eridani	3	1	+0·006	+0·0151	+0·0091	35·4	−24
27 Persei κ	3	4	+0·016	+0·0256	+0·0096	30·6	+45
Bradley 431	3	4	−0·025	+0·0328	+0·0578	21·5	+77
Bradley 445	1	2	+0·001	−0·0248	−0·0258	19·1	+65
Bradley 480	3	7	+0·009	+0·0216	+0·0126	28·7	+48
Bradley 496	5	5	+0·009	−0·0017	−0·0107	24·8	0
Piazzi III. 104	3	4	+0·025	−0·0019	−0·0269	24·4	+37
Bradley 569	3	1	+0·007	−0·0073	−0·0143	19·9	+ 9
49 Tauri μ	3	1	+0·003	−0·0037	−0·0067	37·0	+ 9
Piazzi IV. 31	1	5	−0·002	+0·0248	+0·0268	25·5	+41
66 Tauri r	4	5	+0·003	−0·0052	−0·0082	33·0	+ 9
77 Tauri θ'	2	3	0·000	+0·0133	+0·0133	28·9	+16
55 Eridani	6	3	+0·005	−0·0145	−0·0195	14·3	− 9
Bradley 661	2	5	+0·016	+0·0024	−0·0136	25·9	+36
5 Aurigæ	5	5	+0·004	−0·0146	−0·0186	25·2	+39
11 Camelopardali	2	5	+0·003	−0·0183	−0·0213	26·1	+59
12 Camelopardali	1	5	+0·004	−0·0281	−0·0321	26·0	+59
4 Leporis κ	3	1	+0·003	−0·0152	−0·0182	34·9	−13
108 Tauri	2	1	+0·003	+0·0254	+0·0224	35·9	+22
8 Leporis	2	1	0·000	+0·0107	+0·0107	34·8	−14
Bradley 755	4	1	+0·007	−0·0074	−0·0144	28·3	+34
115 Tauri	9	1	−0·002	+0·0056	+0·0076	34·2	+18
26 Aurigæ	1	2	−0·004	+0·0075	+0·0115	30·4	+30